Arnold Schwarzenegger
Governor

Gas Fired Heat Pump for Heating and Refrigeration in Food and Beverage Industry

FINAL REPORT

PIER FINAL PROJECT REPORT

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This work builds on technology developed under a U.S. Department of Energy, National Energy Technology Laboratory project, “Multipurpose Commercial Hot Water Gas Heat Pump”.

PREFACE

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Energy Commission), annually awards up to $62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy-Related Environmental Research
- Energy Systems Integration Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies

What follows is the final report for the **Gas Fired Heat Pump for Heating and Refrigeration in the Food and Beverage Industry,** Contract # 500-01-0128, conducted by **Energy Concepts Co**. The report is entitled *Gas Fired Heat Pump for Heating and Refrigeration in the Food and Beverage Industry* . This project contributes to the Industrial / Agricultural / Water End-Use Energy Efficiency program area.

For more information on the PIER Program, please visit the Energy Commission's Web site www.energy.ca.gov/pier/reports.html or contract the Energy Commission at (916) 654-5200.

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ABSTRACT

ThermoSorber™, a thermally driven heat pump that delivers hot water and chilling simultaneously, was developed and demonstrated at a California food processing plant. It is driven by heat at ~300°F , delivers hot water at ~140°F, and provides chilling at ~35°F. It provides 160 units of heating and 60 units of chilling per 100 units of thermal energy input. Electrical energy use is minimal at ~6 units of thermal energy equivalent. Rejection of the heat extracted from the chilling load at a temperature high enough to be useful in industrial application is the concept behind this highly energy efficient device.

The heat pump is a unique ammonia-water cycle, developed by Energy Concepts Company (ECC). The heat pump also uses proprietary heat and mass exchangers, which allow the delivery of the two useful energy products (hot water and chilling), at very high efficiency. The heat pump was designed, fabricated, and tested at ECC; shipped to the food processor; installed and commissioned; and has now operated for over 20 months. Other food and beverage processors have been offered a ThermoSorber, but for reasons not related technical or economic considerations, have not yet accepted the offer. Specifications, operating results, lessons learned, and commercialization plans are detailed.

This report describes the first field demonstration of the ThermoSorber™ – a thermally driven combination chiller / heat pump . The ThermoSorber produces hot water plus chilling using only one half the energy of any other available technology. The savings in both utility cost and energy are large, and the installed cost is low. This results in attractive paybacks of less than two years in most applications.

EXECUTIVE SUMMARY

The Food and Beverage Industry in California spends a large percentage of its operating expenses on energy. The FIER activities of the PIER Program are dedicated to lowering those energy costs. This project aims to develop and demonstrate a revolutionary new technology to this industry, for widespread application, to lower energy usage (and cost).

Food processors currently use gas or electric hot water heaters or gas boilers to produce hot water; and electric mechanical vapor compression systems to supply chilling. These two systems account for a large portion of the facility's overall energy usage. ThermoSorber was developed by Energy Concepts to provide heat pumped hot water and chilling, with cost share assistance from the National Energy Technology Laboratory.

Energy Concepts designed a ThermoSorber that would meet the specific load requirements of the intended demonstration sites. Two units were fabricated, the first one tested extensively at Energy Concepts, and the second unit incorporating the lessons learned from the first unit. The unit was extensively tested for performance, safety, and off design operation. The unit was shipped to Squab Producers of California, installed, and commissioned. Squab personnel were trained in ThermoSorber operation.

Several modifications were required over the initial months of testing to achieve design performance. Overall, installation of the ThermoSorber has allowed the site to maintain more consistent hot water temperature; more easily meet refrigeration loads; and reduction in run time of the air coil fan.

Additional demonstration sites were explored (approximately 20), and due to non-technical business reasons, declined to participate or deferred the decision. Energy Concepts will continue to seek additional demonstration sites, particularly in the California food processing sector. ThermoSorber has been presented at state-wide and national level conventions and trade shows. Additional marketing activities, such as advertising and utility incentive programs, will occur once more demonstrations are underway.

1.0 Introduction

1.1. Background

Many food and beverage industries require heating and chilling for process and storage applications. Gas-fired boilers supply the heat while electrically driven refrigeration systems provide the chilling. The cost of energy consumed by these devices is a major concern. This project advances a new technology which provides a unique solution to this problem – a heat-activated heat pump. Gas hot water heat pumps transfer heat from a lower temperature to a higher temperature. They produce chilling and heating at the same time using only a fraction of the energy required by conventional technology. However, industry is not familiar with this new technology.

Conventional electric hot water heat pumps also deliver hot water. However they generally pump the heat from ambient temperature rather than from chilling temperature, and consume expensive electricity. Conventional absorption chillers provide heat-activated chilling, but the reject heat is sent to a cooling tower since it is not hot enough to make hot water. The ThermoSorber is the first thermally driven heat pump which has high enough lift to simultaneously produce chilling and hot water.

The ThermoSorber was initially developed with cost share assistance from the U.S. Department of Energy, through the National Energy Technology Laboratory (NETL). However, a planned field demonstration was not accomplished due to a realignment of responsibilities at DOE. All absorption activity was transferred from the buildings division to the power division, and since the ThermoSorber doesn't produce power, it was dropped. Hence this California Energy Commission project is the first field demonstration of the ThermoSorber.

1.2. Project Objectives

The objective of this project is to demonstrate a heat-activated hot water heat pump, ThermoSorber™, in the food and beverage industries. The proposed technology approximately doubles the energy efficiency of co-producing hot water and chilling. This project has shown that the economic payback of the ThermoSorber in reducing utility (gas and electric) costs can be attractive (less than two year payback) even at this early commercialization stage.

This project meets the PIER Goal of reducing the cost of California's electricity.

The quantitative objective of this project is to demonstrate it is possible to reduce consumption of natural gas 40% in hot water production, along with an 80% reduction in electricity to produce the associated chilling.

1.3. Report Organization

This report describes the tasks performed during this project. The application targeted for demonstration is described. The demonstration site, installation, operation, and modifications are detailed. The project results are quantified in Section 3. Other potential demonstration sites are described (energy savings potential, application to existing process) and explanations are given for why the second field demonstration has not yet commenced. Plans for continuing commercialization of this technology are described.

2.0 Project Approach

The work scope involved the following tasks:

Task 1

Attend Kick-off meeting and document match funds – accomplished.

Task 2.1 Application Requirements and Constraints, and Test Plan

These are described below and in the accompanying figures and table. Figure 2 gives an overview of the ThermoSorber interfaces with the Squab chilling and hot water systems. Figure 3 gives a schematic of the refrigeration system at Squab and the ThermoSorber interface exchangers.

Task 2.2 ThermoSorber Design Modification

The objective this task was to modify the original ThermoSorber design to meet the hot water demand and chilling requirements at the Squab Producer of California ("Squab") plant.

The technical approach for this task was as follows:

1. Analysis of the existing hot-water supply and chilling system at Squab ;
2. Thermodynamic analysis of the ThermoSorber to determine optimum process parameters;
3. Preparation of P&ID and specification of controls;
4. Sizing of ThermoSorber components; and
5. Preparation of drawings and design specifications.

Design modifications were identified for the baseline ThermoSorber design which had been developed in the NETL project. With minor changes this design was expected to be applicable to the second site. ECC and Squab evaluated several options and their benefits were analyzed to determine an optimum interfacing of the ThermoSorber with the plant for maximizing the overall natural gas and electric savings. Based on the hot water demand, the ThermoSorber was designed for 9.3-ton chilling capacity.

The major issue in this task was that the ThermoSorber chilling could not be connected to a single source in the existing refrigeration system. The distributed chilling load complicated the design and controls. Although the total chilling load approached 30 tons, no single load presented the 9.3 tons which was required to meet the hot water load.

Figure 1 is a simplified schematic diagram of a ThermoSorber. All sizes of ThermoSorber, from 15 tons to 150 tons, use this basic flowsheet with appropriately scaled components. Ammonia water solution is heated in the Generator. At Squab, the source of this heat is a high temperature hot water boiler. Squab did not have a hot water boiler of sufficient capacity, so it had to be supplied by this project. The two-phase solution flows to the Rectifier, where pure refrigerant vapor is obtained. This vapor goes to the condenser, where it is condensed so as to supply heat at the low temperature end of the hot water product. Refrigerant liquid then goes to the evaporator, via a Refrigerant Heat Exchanger (RHX). This internal heat exchange increases the cycle efficiency. The evaporator produces chill glycol, which is sent to the various plant refrigeration locations. Low-pressure ammonia vapor from the evaporator is routed to the absorber, where it is absorbed back into the liquid solution (from the rectifier). When all the vapor is absorbed, the solution is pumped back to the generator. More internal heat recovery is accomplished in the Solution Heat eXchanger (SHX), which also increases the cycle efficiency. The absorption step is exothermic, and the concentration of ammonia is controlled so that this step supplies the high temperature boost to the product hot water.

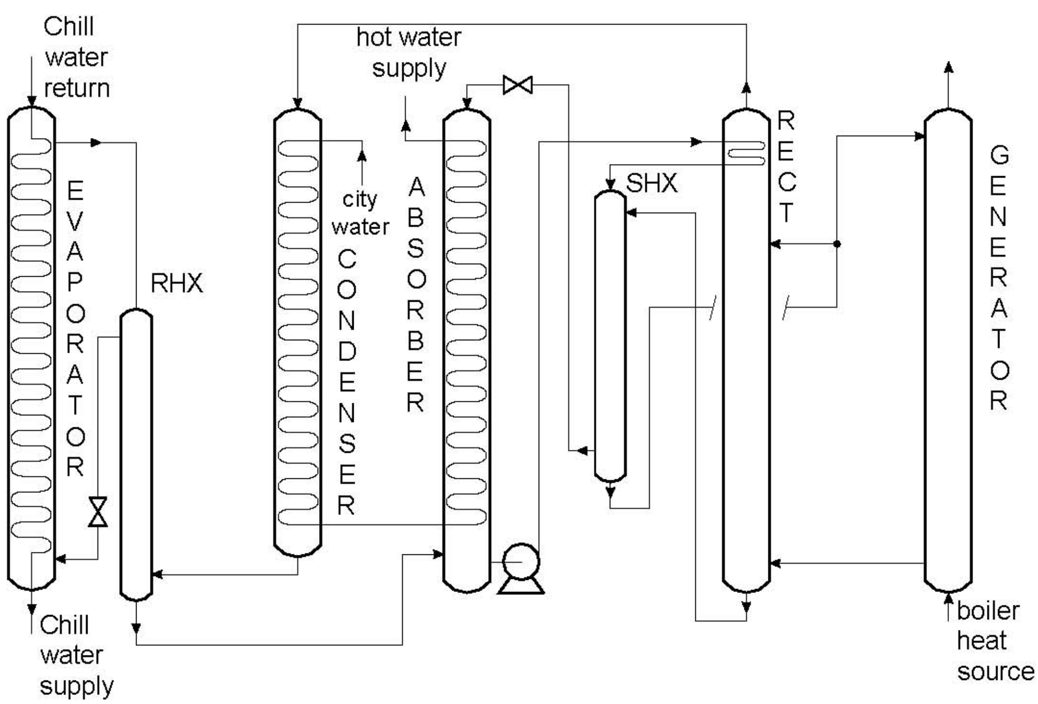


Figure 1 ThermoSorber Schematic Flowsheet

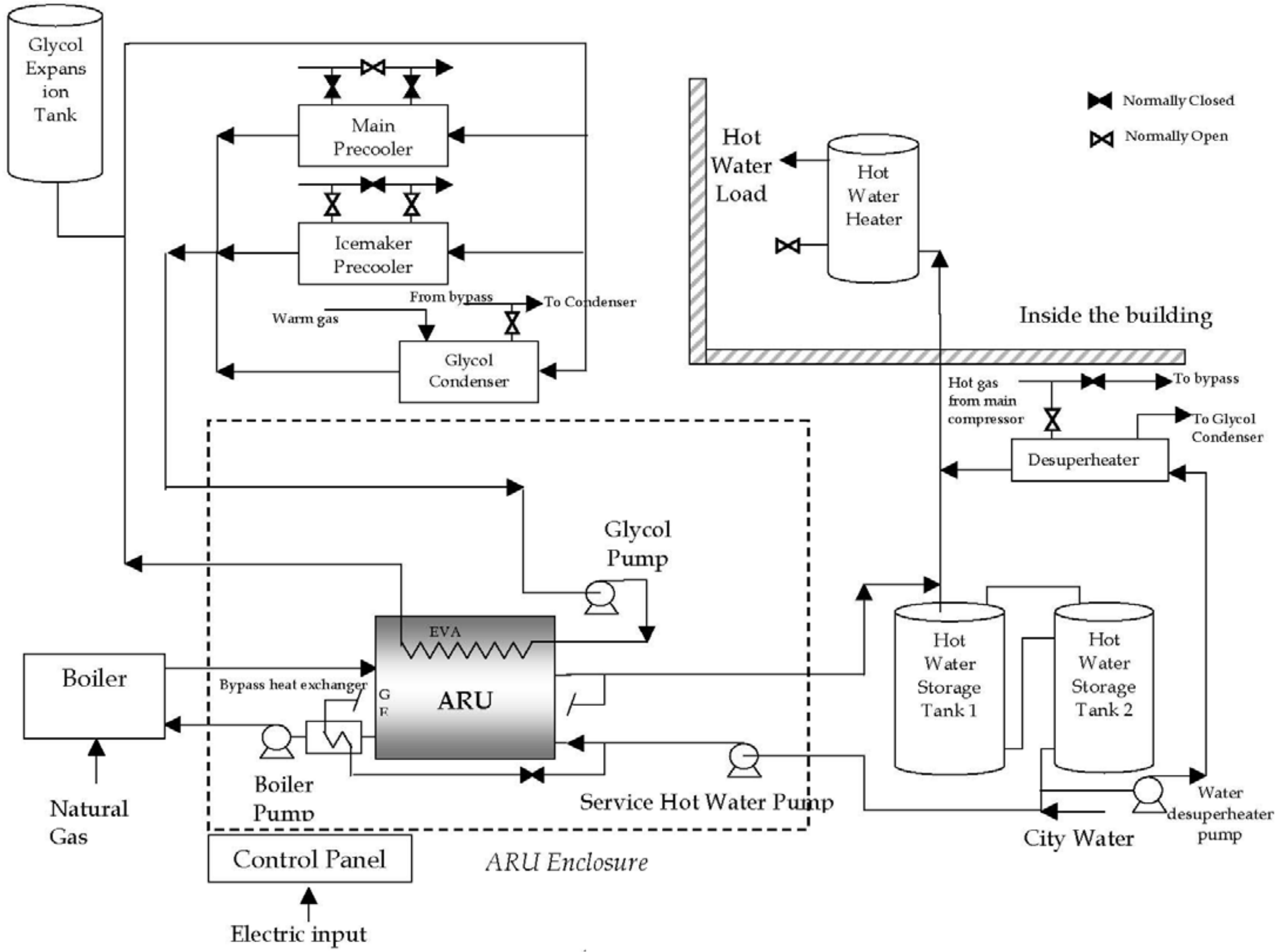


Figure 2 System Diagram - ThermoSorber Installation at Squab Producers of California

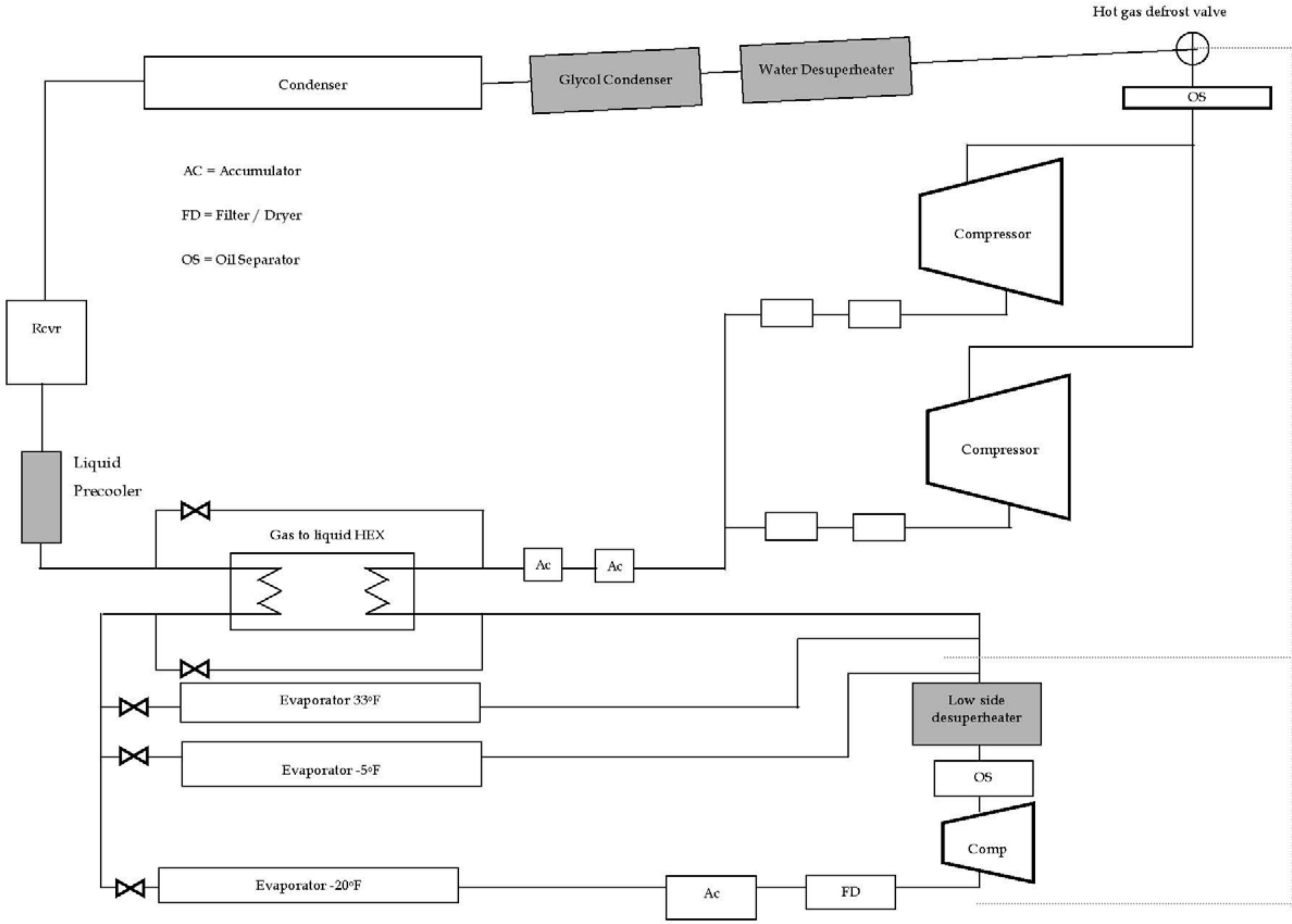


Figure 3 Simplified Schematic of Main Refrigeration Unit at Squab Producers

Task 2.3 Site Preparation

The objective of this task was to prepare the Squab plant site in preparation for installing the ThermoSorber. This required interfacing with the existing hot water supply, chilling load, and utilities (natural gas and electricity).

The technical approach was as follows:

1. Obtain information on the existing hot-water supply and chilling system at Squab;
2. Prepare interfacing schematics and identify controls;
3. Identify major technical issues of interfacing;
4. Pour concrete pad for the ThermoSorber, hot-water storage tank, and boiler;
5. Pipe the service water to the ThermoSorber and the hot-water supply to the existing water heater;
6. Install the three chiller heat exchangers;
7. Supply 3-phase 208 V electric service to the ThermoSorber; and
8. Pipe the natural gas supply to the ThermoSorber pad
9. Specify and procure hot water tanks.

The major issue in this task was to determine the code requirements for installing the hot water boiler and other components, and designing the hot-water storage system.

Task 2.4 Procurement of Components and Parts

The objective of this task was to specify, bid out, select, and purchase parts and components for the ThermoSorber model TS15 to be installed at Squab. There are eight major components in a ThermoSorber:

- Generator
- Rectifier
- Absorber
- Condenser
- Evaporator
- Solution Pump
- RHX
- SHX

Two of these were designed and fabricated by ECC, using proprietary heat exchange and fabrication technology. The remaining six components were competitively bid and purchased from commercial vendors. Special importance was attached to materials selection, since ammonia-water solution is incompatible with several common refrigeration materials (copper, brass, Viton).

Task 2.5 Fabrication of Two ThermoSorber Units

The objective of this task was to fabricate both a test ThermoSorber and also the ThermoSorber for delivery to Squab.

This task included fabrication of two sets of critical components at ECC; fabrication of the frame; assembly of components onto the frame; installation of control and monitoring equipment; leak testing; insulation; and final packaging. The first unit was fabricated and then tested extensively, revealing several shortfalls in desired performance which required design modifications. Those modifications were incorporated in the second unit, destined for Squab. That unit was also subjected to extensive performance testing prior to final packaging, as detailed below.

The major shortfall of the first fabricated unit was one component (rectifier) which did not meet the original design performance. A new rectifier was constructed with additional surface area, and was installed in the second unit. The new rectifier met the performance goals.

Task 2.6 Operational Testing at Energy Concepts Company

The objective of this task was to verify operation and performance of the ThermoSorber using simulated hot water and chilling loads before the unit was shipped to Squab. It included the following activities:

1. Install the ThermoSorber in the ECC test facility;
2. Check ThermoSorber operation: on/off, steady state controls, and safety devices;
3. Obtain performance data with boiler temperature of 250°F;
4. Perform cycle analysis to predict the performance at a boiler temperature of 305°F for the Parker boiler to be installed at Squab Producers; and
5. Determine performance at partial chilling load to simulate operation of the ThermoSorber without icemaker chilling load. This was based on the information that all of the refrigeration plant ran continuously 24/7 except the icemaker.

<u>Operation</u>: The operation of the ThermoSorber at design conditions was found to be stable without excessive cycling. Tests were performed to check the on/off function. The on/off switch will be activated by a thermocouple on the hot water tank. In the absence of a hot water tank, the on/off switch was activated with equivalent temperature of water flowing from the cooling tower. In order to simulate the change in temperature of the hot water tank, the cooling tower fan was operated at low speed, so that water temperature increased with the ThermoSorber running. As the cooling tower water temperature reached the high-temperature

set point, the on/off switch turned the ThermoSorber off. With the ThermoSorber off, the cooling tower water then slowly cooled down. When the water temperature dropped below the low-temperature set point, the ThermoSorber restarted. This on/off operation was checked several times to ensure its functionality.

Performance: Tests were performed at different boiler water temperatures. The ThermoSorber settings were adjusted for each boiler temperature, specifically the solution flow rate, to obtain optimum performance. The results from the ECC tests provide the basis for setting the operating parameters and controls for optimum performance at Squab. Tests were also conducted at partial chilling load. The test results met the performance requirements, supplying the desired hot water and chill water temperatures at up to 11-ton chilling capacity. The quantitative test results are presented in Section 3.

Task 2.7 Shipment, Installation and Startup

The objective of this task was to prepare the ThermoSorber and system components for shipment to Modesto; ship the items; install the ThermoSorber system components; test all systems for operation and safety; start the system; and train Squab personnel on the operation of the ThermoSorber.

After fabrication and testing, the ThermoSorber TS15 was packed for shipment, shipped, and arrived in Modesto the week of March 2003. Energy Concepts personnel arrived later in the week to install and start up the unit.

The boiler and water storage tanks had arrived at Squab earlier; a concrete pad had been poured by Squab, and electrical and gas connections had been run to the pad. ECC personnel hooked up the gas boiler; piped the storage tanks to the TS15 and to the water heater connections. ECC attached all plumbing circuits to the TS15, installed three interface pumps, and ran glycol lines to and from existing Squab refrigeration equipment. Brazed plate heat exchangers were installed in the refrigeration system by Squab personnel and their contractor. One modification was made from the original design: it was determined that preventing ice-up conditions in the icemaker water pre-cooler would limit the other heat exchangers, so the icemaker water heat exchanger was replaced with a de-superheater on the R408A refrigerant line (low side compressor discharge vapor), plus a precooler in the icemaker freon supply. After utilities were connected, ECC charged the ThermoSorber with corrosion-inhibited distilled water and with refrigerant grade ammonia. Then the unit was started, test operated, and controls were appropriately adjusted.

ECC provided Squab with training on operation of the absorption cycle, the interface components, "what-if" scenarios, safety procedures, and the monitoring process. A manual with flowsheets, wiring diagrams, component specifications, procedures, contact lists, and safety procedures was provided to Squab. A data sheet was prepared for data collection.

Figure 4 ThermoSorber TS15 Installed at Squab Producers of CA

During the installation and start-up of the ThermoSorber, two energy saving issues with the existing hot water and refrigeration systems were identified:

- It was discovered that Squab was using more hot water than they realized – more than required by FDA guidelines, since there was no hot water flow meter.
- The icemaker refrigeration plant was undercharged with freon, which caused the unit to operate for a longer period of time to produce the desired amount of ice.

The water flow was reduced to about 7 gpm, which the ThermoSorber can supply with adequate chilling load (>6 tons). In order to prevent the icemaker compressor from frosting, the ThermoSorber heat exchanger for the icemaker was bypassed. It resulted in reduced chilling load for the ThermoSorber, which resulted in reduced hot water temperature. The problem has been corrected by installing a heat exchanger to extract heat by condensing refrigerant. During the summer, when the refrigeration load increases, the condenser heat exchanger can be bypassed and provide necessary chilling to both the main refrigeration unit and the icemaker.

Task 2.8 Performance Monitoring and Testing

The purpose of this task is to document the benefits realized by Squab from the ThermoSorber, to quantify the thermo performance and the energy savings, and to summarize the lessons learned in the process of achieving reliable system operation. The results of this task are presented in Section 3 of this report.

Task 2.9 Technology Transfer Activities

There are presently three approaches to technology transfer:

1. Pursue more field demonstrations, illustrating larger capacities, different applications, and better paybacks. There is no substitute for actual demonstrations in the difficult process of gaining acceptance of new technology.
2. Publicize the technology in any likely forum. This includes presentations at conferences, and journal articles.
3. Empower a network of distributors who understand the technology and are searching for more applications. Thus far we have six distributors in California.

To date the most effort has gone into finding additional demonstration sites. Over 15 California sites have been assessed, and site visits have been made to ten of them, with individual presentations of the technology. These efforts are summarized in Section 3.

Task 2.10 Production Readiness Plan

Since the Modesto Squab installation, Energy Concepts has designed, fabricated, and tested seven more ThermoSorbers, covering a range of capabilities, capacities, and operating conditions. We have incorporated many improvements into the design: improved components, improved flowsheet, and improved controls. We have tried numerous variations in the layout, to identify that which is simple not only to fabricate, but also to operate and maintain. We have developed procedures and obtained equipment necessary to enable production of up to 30 units per year.

Task 3 Reporting – Progress Reports; Final Report – accomplished.

3.0 Project Outcomes

The design modifications were successfully accomplished, as demonstrated by the results of the factory acceptance testing. Table 1 presents these results.

The installation was relatively straightforward. It required 15 man-days of effort, including charging, commissioning and training. A photograph of the completed installation is shown in Figure 4.

3.1. Operational Results

The hot water storage system worked very well. The system is designed so as to allow the same tanks to store both cold water and hot water, using thermal stratification. In that way, the hot water pump can be a single low head circulating pump, rather than a pressurizing pump. This concept requires that the thermal stratification boundary between hot and cold water, which moves frequently, only take up a minimum of tank volume. We found it to only require about 12” of height, which meets that criterion.

Over time, numerous problems developed which required resolution. Some were related to the ThermoSorber; some to the main refrigeration unit; and some to the interface between the two.

Solution to Problem 1. Leaking Glycol Piping

The chill glycol system was originally piped with CPVC, which is rated up to 180°F. The hot water demand only requires the ThermoSorber to operate seven hours per day. When it is idle, the glycol loop heat exchanger on the low side compressor discharge heats up to the discharge temperature. It turned out to be above 180°F, since the glycol piping sagged and developed numerous leaks. We had to replace the affected piping section with copper. Eventually, the entire chill glycol system was changed to copper. As part of that change, we added a desuperheater which heats a parallel stream of hot water. That has helped prevent any subsequent glycol overtemperature events.

Solution to Problem 2. Thermosorber Cycling

The ThermoSorber was originally controlled only by a thermocouple at the full end of the hot water storage tank. When the system was idle, that end of the tank slowly cooled down, and triggered a start signal. That involves a start signal to the hot water boiler, some time to get it up to temperature, and then a start signal to the ThermoSorber. This would happen several times per night, and was wasteful of natural gas. This problem was corrected by adding a timer to the ThermoSorber to keep it off until the work shift commenced.

Solution to Problem 3. Thermosorber Leaks

This early model ThermoSorber used flanges and pipe joints for most connections – in the newer models they are almost all welded. With the mechanical joints, thermal cycling can cause leaks to appear over time. One leak proved to be particularly difficult to find – the flange connecting the generator to the rectifier, which is the hottest location of the cycle. This leak was under thick insulation. Slowly all the leaks were fixed, including replacement of several valves with more robust designs.

Table 1 Performance Verification Results

		Design		ECC Test Results					
		Squab conditions	ECC conditions	Test 1 010403	Test 2 010603	Test 3 011403a	Test 4 011403b	Test 5 011403c	Test 6 011503
Water Temperature [F]	Generator-in	305.1	249.1	254.5	263.3	266.0	276.3	263.8	280.2
	Condenser-in	69.1	63.5	64.2	63.3	60.4	64.6	64.4	61.7
	Absorber-out (Supply to Squab hotwater heater)	142.0	132.1	129.1	132.0	138.4	141.9	129.0	138.4
	Evaporator-in	50.2	52.3	52.9	51.6	51.3	53.1	53.1	50.9
	Evaporator-out	35.1	37.9	36.3	37.4	35.4	37.0	38.1	35.8
Performance	Chilling capacity [tons]	9.3	8.7	10.2	8.5	9.4	9.5	10.2	9.8
	COP_cooling	0.548	0.577	0.567	0.575	0.540	0.552	0.562	0.546
	COP_heating	1.549	1.580	1.570	1.579	1.542	1.554	1.564	1.547
Flow Rate [gpm]	Pump	2.26	3.03	3.69	2.45	3.23	3.14	2.80	2.04
	Letdown	1.66	2.47	3.04	1.91	2.64	2.54	2.16	
	Condenser	8.64	8.33	8.92	8.21	8.31	8.36	10.56	8.67
	Absorber	8.64	8.33	10.49	8.21	8.31	8.36	10.56	8.67
	Chilled Water	14.56	14.56	14.80	14.40	14.25	14.20	16.27	15.46
	Boiler Water	10.14	36.76	63.13	58.83	55.90	59.11	62.01	56.00
Pressure [psig]	Rectifier	188.5	168.5	165.0	158.0	153.0	160.0	154.0	149.0
	Absorber	42.9	43.2	40.4	38.8	31.5	33.0	34.0	38.0
Ammonia Concentration [wt. fraction]	Refrigerant	0.989	0.989	0.991	0.991	0.989	0.988	0.990	0.988
	Absorber - outlet	0.388	0.411	0.381	0.388	0.363	0.361	0.385	0.408
	Generator - outlet	0.206	0.299	0.270	0.244	0.244	0.235	0.234	0.197
Heat Duty [Btu/hr] 1000	Condenser	119	112	132	110	123	125	132	129
	Refrigerant HX	13	9	12	7	9	10	10	9
	Evaporator	111	104	123	103	113	115	122	117
	Absorber	195	173	207	171	200	198	208	203
	Solution HX	54	92	132	71	90	90	95	46
	Vapor generator	203	180	216	178	209	207	218	215
UA [Btu/hr F] 1000 (Heat transfer coefficient X area)	Condenser	7.5	7.6	9.7	8.1	9.0	10.2	10.8	11.8
	Refrigerant HX	1.2	1.2	1.5	0.9	1.0	1.2	1.3	1.2
	Evaporator	11.9	12.0	10.8	12.4	10.8	11.2	12.8	13.3
	Absorber	6.3	7.6	7.3	6.2	9.2	8.9	8.0	7.8
	Solution HX	1.1	3.0	7.7	5.2	6.3	6.0	5.4	
	Vapor generator	7.9	8.7	15.8	11.4	12.8	12.0	15.3	9.7

Solution to Problem 4. Compressor Failures

The refrigeration plant at Squab is quite old, having been moved there from another facility over 30 years ago. It had a history of compressor failures, but by the time of this project, measures had been incorporated which had prevented compressor failure for over four years. Unbeknownst to either us or the Squab staff, one of those measures had been to override the compressor thermostat and keep it running 24/7 (except for brief defrost periods). Once the ThermoSorber was in operation, the cold storage room temperatures became colder, finally dropping below their setpoints. This was what triggered the discovery of the thermostat override. Approximately two months after the ThermoSorber was installed, the thermostat was restored to operation. Approximately one month later, a compressor failure was experienced, requiring a rebuild. Over the succeeding six months, at least two more compressor failures were experienced. The failure analysis from the compressor manufacturer indicated bearing wipes consistent with loss of lubrication due to excess liquid refrigerant. It is hypothesized that this was caused by the compressor shutting down while the ThermoSorber was running, either from defrost signal or from thermostat signal. Then the ThermoSorber, having greatly reduced chilling load, pulls down to its stagnation temperature. At about 0ºF, vapor refrigerant will start to condense in the low side compressor discharge heat exchanger, and that vapor possibly gravity drained back to the compressor, causing the problem. Note this can only happen when the compressor is off, and it can only happen when the ThermoSorber chill glycol gets extremely cold. It would be possible to put controls on the ThermoSorber to turn it off before such extreme cold is produced. However, since we weren't 100% convinced that this was the compressor failure mechanism, another corrective action was instituted.

In order to establish the least possible interaction between the main refrigeration unit and the ThermoSorber, the chill glycol heat exchanger was relocated to the condensing duty for the two high side compressors. Thus it is immediately upstream of the air coil, and the primary effect is to reduce the run time of the fan for the air coil. There is also a small amount of head reduction for the compressors, which slightly reduces their power draw. Usually this technique does not save as much power as liquid precooling. However the main refrigeration unit at Squab has suction line heat exchangers, which eliminate about half the benefit of precooling, so the new high side configuration may be saving a comparable amount of electric power. It is parenthetically noted that SLHXs have been virtually eliminated from modern refrigeration plants, as they have been shown to rarely if ever provide any actual net benefit.

Since the compressor discharge temperature exceeds 200ºF, it was considered appropriate to install a desuperheater to do some direct water heating first, to cool it closer to saturation, and then use the glycol. This protects the glycol loop from over –temping, and also picks up another 15% of water heating capacity beyond that provided by the ThermoSorber. This is particularly useful at night when the ThermoSorber is off, keeping the storage temperature up.

3.2. Benefits to Squab

The most significant benefit to date has been the improved temperature control in the scalder. Compared to the old method of feeding cold water and sparging in steam manually, the occurrences of over-temperature and resulting product spoilage have been nearly eliminated.

The air coil fan now runs substantially less, and the compressors don't work as hard, having a lower discharge pressure. This should extend their operating life.

The various refrigeration loads are now easily met, whereas it was previously a strain to keep up with these loads in summer months.

More attention is now focused on hot water consumption in particular, and energy conservation in general.

There has been a slight reduction in utility bills, and some further reduction can be anticipated now that the system is stabilized and debugged.

3.3. Subsequent Demonstrations

Efforts are continuing to implement additional demonstrations. The originally proposed second demonstration site (Butterfield Brewery in Fresno) has relocated, and didn't have sufficient hot water demand. Approximately twenty other sites have been explored, and a few have expressed desire or willingness to host a demonstration. The delays have been due to many factors:

1. In the larger facilities where ThermoSorber operation would be 24/7 and hence the savings very large, the decision and approval process for new projects is cumbersome and lengthy. Usually capital expenditure budgets are proposed once per year.
2. None of the contacts made had ever heard of ThermoSorber, and several were skeptical or disbelieving that the claims could be true.
3. Most contacts either had previous experience or knew of energy projects that fell far short of the claims, adding to the skepticism.
4. In at least two cases, the contacts were already installing alternative technology which would meet the same needs. The alternatives were much less economic than the ThermoSorber – four year and six year paybacks, compared to two years for ThermoSorber. However, both projects had large government cost share grants – 50% in one case, 80% in the other – which brought their savings up to par with ThermoSorber.
5. The presence of ammonia in the ThermoSorber was cited as a concern in two cases, although many of the others already use it as their refrigerant.
6. Energy Concepts has held discussions with several established manufacturers pursuant to forming an alliance to provide better sales and support, and ultimately volume manufacturing of ThermoSorber. Although there is a level of interest, the

usual stumbling block is that hot water heater manufacturers view this as a refrigeration product, where they have no experience or knowledge. Conversely refrigeration manufacturers view it as a hot water product.

3.4. Marketing Efforts

Marketing is continuing with all of the promising contacts mentioned above. Two of the larger companies have initiated approval requests for demonstration units. One of those is including in the same request an additional six 100 ton ThermoSorbers as a follow-on project.

In our marketing effort, we have found it important that users understand that a ThermoSorber operates differently than conventional technology, in order to get the full savings potential. Typically, hot water is produced and stored in a tank, and chilling is produced by running a compressor (no storage). This is different than the operating principle of the ThermoSorber: when it is producing hot water, it is also producing chilling. However when no hot water is being produced, no chilling is being produced. Therefore load matching is very important to realize the full savings potential.

Every food processing plant has different systems and interfaces for their hot water and chilling. Most often multiple compressors and boilers supply these needs. It is important to connect both of the ThermoSorber outputs to the proper location in the customer's system, to ensure maximum load and operating time for the ThermoSorber, to ensure against any adverse effects to existing equipment, and obtain maximum energy savings.

One promising new marketing avenue is to team with existing industrial refrigeration companies, provided they are interested in new energy-saving technology. Some are not- they are very happy sticking with the compressor systems they know. Others, however, are more forward thinking, and immediately recognize how this technology will benefit many of their existing customers. We are establishing a relationship with one major industrial refrigeration engineering/ contracting firm in the Central Valley.

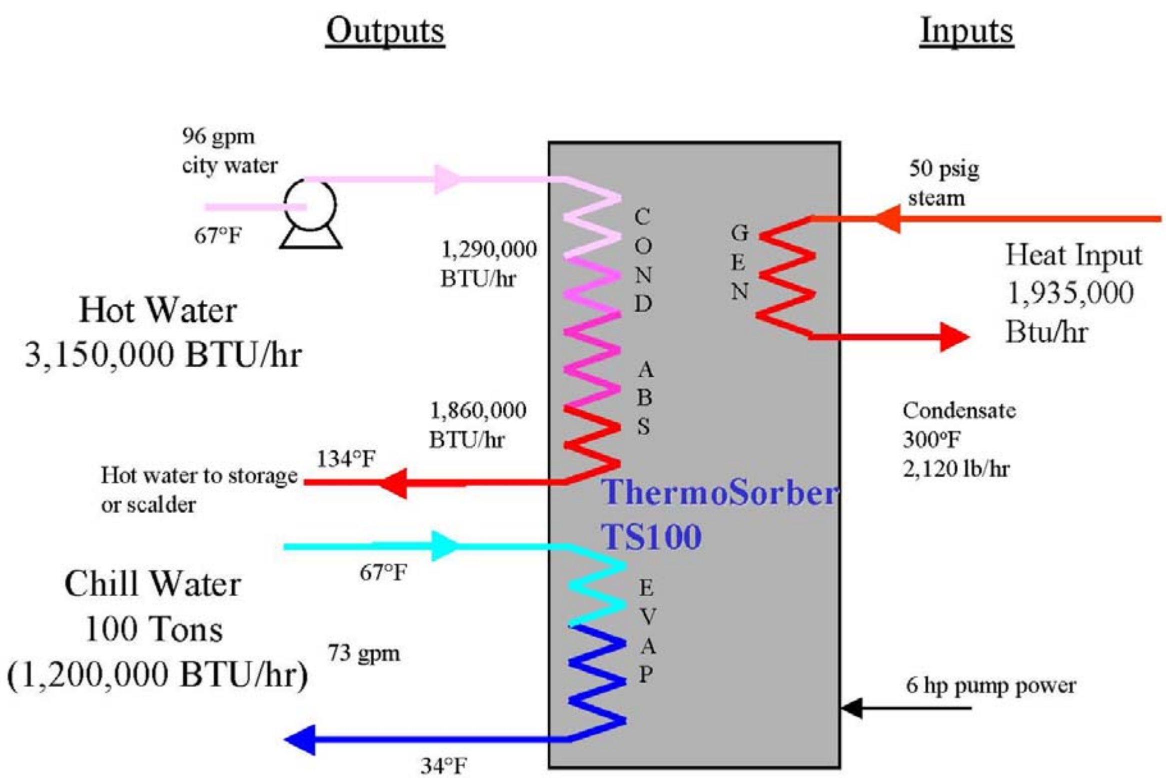
In addition to the direct marketing described above, this technology has been presented at four different public venues, as cited in the bibliography.

3.5. ThermoSorber Economic Case Study

Figure 5 shows the utilities required and supplied by ThermoSorber, and applies costs to those utilities, to derive projected savings. This example was developed for a 100 ton ThermoSorber, which supplies a typical food processor with 140°F hot water and 38°F chilling The gas rate used is $6.00/million BTU, which is typical for industrial users in California. Electric rate is 8¢/kWh. The plant runs for a 12 hour shift, then a 6 hour Clean-in-place shift, six days per week.

The capital costs are as follows: cost of a 100 ton ThermoSorber is $111,000, FOB Annapolis, MD. Shipping and installation are estimated at $20,000, and site preparation estimated at $34,000. The total installed cost of a TS100 is $165,000. With annual savings of $96,258, the customer will achieve a payback of 20 months.

This analysis calculates simple payback on initial investment, considering utility savings only. The customers will also realize the benefit of increased capacity of both chilling plant and of hot water production, which substantially improve the economics.



Hourly savings

Electric:	53 kW load reduction x 8¢ =	$ 4.24/hour
Natural gas:	2.15 MBH x $6/MBH =	12.90/hour
	TOTAL SAVINGS	$17.14 per hour

Annual savings

At 18hour/day,	5616 hour/year	$ 96,258
At 24 hour/day,	7488 hour/year	$128,244

Figure 5 ThermoSorber TS100 Performance Estimate

4.0 Conclusions and Recommendations

4.1. Conclusions

ThermoSorber is a highly promising product with major energy-saving implications. There are many barriers to its successful commercialization, but none that are insuperable. The lack of knowledge and skepticism over this product must be addressed with more demonstrations. Compared to other major energy saving technologies such as distributed generation, the barriers facing the ThermoSorber are really quite minor.

4.2. Commercialization Potential

Any industries that use hot water and chilling at the same time can benefit from ThermoSorber. This includes hotels, gymnasiums, commercial laundries, restaurants, and swimming pools. ThermoSorber will be direct marketed to these industries. Since ThermoSorber provides large increases in energy efficiency, ECC will submit this technology to local utilities for inclusion in their rebate programs. Gas utilities and trade associations will also be approached for marketing support, since this technology displaces electric chilling with (effectively) gas powered chilling.

4.3. Recommendations

More ThermoSorber demonstrations should be fielded. With successful demonstrations, a publicity campaign should be initiated. The ThermoSorber should be explicitly included in utility rebate programs.

4.4. Benefits to California

The benefits to California are the savings in both electricity and natural gas; and the enhanced competitiveness of California industries, especially food processors, due to lower utility costs.

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